SEMI-ANNUAL REPORT
JULY-DECEMBER, 1994
NASA CONTRACT: NAS5-31368
FOR MODIS TEAM MEMBER STEVEN W. RUNNING
ASSOC. TEAM MEMBERS E.RAYMOND HUNT, RAMAKRISHNA R. NEMANI
15 JANUARY 1995

PRE-LAUNCH TASKS PROPOSED IN OUR CONTRACT OF DECEMBER 1991

We propose, during the pre-EOS phase to: (1) develop, with other MODIS Team Members, a means of discriminating different major biome types with NDVI and other AVHRR-based data. (2) develop a simple ecosystem process model for each of these biomes, BIOME-BGC based on the logic of the current FOREST-BGC; (3) relate the seasonal trend of weekly composite NDVI to vegetation phenology and temperature limits to develop a satellite defined growing season for vegetation; and (4) define physiologically based energy to mass conversion factors for carbon and water for each biome.

Our final core at-launch product will be simplified, completely satellite driven biome specific models for ET and PSN based on this modified ‰NDVI logic. These algorithms will be in MODISDIS before launch. We will build these biome specific satellite driven algorithms using a family of simple ecosystem process models as calibration models, collectively called BIOME-BGC, and establish coordination with an existing network of ecological study sites in order to test and validate these products. Field datasets will then be available for both BIOME-BGC development and testing, use for algorithm developments of other MODIS Team Members, and ultimately be our first test point for MODIS land vegetation products upon launch. We will use field sites from the National Science Foundation Long-Term Ecological Research network, and develop Glacier National Park as a major site for intensive validation.

OBJECTIVES:

We have defined the following near-term objectives for our MODIS contract based on the long term objectives stated above.

- Organization of an EOS ground monitoring network with collaborating U.S. and international science agencies.
- Develop advanced logic for landcover classification using carbon cycle simulations from BIOME-BGC.
- Develop improved algorithms for estimating LAI and FPAR for different biome types from AVHRR data.
- Development of a generalized ecosystem process model, BIOME-BGC, for the simulation of the carbon, water and nitrogen cycles for different biomes.
- Implementation of the Global Ecological Simulation System (GESSys).
- Use GESSys to estimate continental net primary production (NPP) and Ó for the globe.
- Begin formal software engineering of our MODIS products, #14

Leaf Area Index and Fraction Absorbed Photosynthetically Active Radiation, and Daily Photosynthesis - Annual Net Primary Production, #16 and 17.

WORK ACCOMPLISHED:

Our MODIS Team now consists of SWRunning, Team Member, E.R.Hunt Jr. and R. Nemani, Associate Team members, and Joe M. Glassy, Software Engineer. The following will be reports on individual activities during this reporting period.

ACTIVITIES OF SWRunning - Team Member

EOS-IWG

SWRunning was elected Chair of the EOS Land Panel in September. This position requires attendance at all IWG meetings and all EOS Science Executive Committee meetings. The first Land Panel meeting was held at the IWG meeting in October 1994.

Organization of an EOS ground monitoring network with collaborating U.S. and international science agencies.

EOS-LTER

A joint proposal to NASA and the National Science Foundation was completed and submitted November, 15 1994. It is now under review.

Global Terrestrial Observing System (GTOS)

SWRunning participated in a meeting of the joint Global Climate and Global Terrestrial Observing System (GCOS-GTOS) Terrestrial Observing System Janaury 9-11 in Asheville, North Carolina. An organized international network of field sites for validating MODLAND science products is in the planning stages.

GAP Analysis Project

The GAP analysis project is a USNational Biological Service funded project to map wildlife habitat in each state using high resolution satellite imagery. I have contacted the national GAP office about sharing their database with the MODLAND team to use as a validation source for our Landcover algorithm. Details of this agreement are being developed.

IGBP Biospheric Aspects of the Hydrologic Cycle (BAHC)

The IGBP-BAHC SSC also met in Wallingford, UK July 14-16. a workshop for designing a network of coordinated trace gas flux towers globally is scheduled that has high importance for EOS MODLAND product validation.

BOREAS project

We plan for BOREAS to provide us with a wealth of field data for MODLAND algorithm testing and validation. Field measurements of LAI, FPAR and NPP are all part of the BOREAS experiment. A BOREAS modeling test was reported on during a meeting during IFC-2 on July 23-24 in Prince Albert, Saskatchewan. SRunning also attended the BOREAS Science Team meeting in December 1994

A Journal article summarizing the products planned by MODLAND during the EOS era.

The MODLAND manuscript was finally published in the International Journal of Remote Sensing. See reference below.

MEETINGS ATTENDED (SWR)

Ecological Society of America annual Meeting, August 1994, Knoxville, TN

Hosted meeting on "Pre-launch MODIS simulation data", Chaired by Al Fleig, GSFC. Flathead Lake, Montana September 1994

MODIS Science Team Meeting, October 1994

EOS-IWG Meeting October 1994

"Workshop on Desktop Computer Environment in the EOS Era, November 1994.

PUBLICATIONS (SWR)

Running, S.W., C. Justice, V. Salomonson, D. Hall, J. Barker, Y. Kaufmann, A. Strahler, A. Huete, J.-P. Muller, V. Vanderbilt, Z. M. Wan, P. Teillet, and D. Carnegie. 1994. Terrestrial remote sensing science and algorithms planned for EOS/MODIS. International Journal of Remote Sensing 15:3587-3620.

Running, S.W., T.R. Loveland, L.L. Pierce, & E.R. Hunt, Jr. 1994. A remote sensing based vegetation classification logic for global land cover analysis. Remote Sensing of Environment (in press).

ACTIVITIES OF E.R.Hunt, Assoc. Team Member

Objectives (ERH)

My first objective was to lead the NTSG effort for global carbon simulations in collaboration with C. David Keeling and Steven Piper at the Scripps Institution of Oceanography.

My second objective was to test BIOME-BGC predictions for three different ecosystems, a tall-grass prairie at the FIFE site near Manhattan, Kansas, a deciduous forest site at Oak Ridge, Tennessee, and a northern hardwood site in New Brunswick, Canada. Testing BIOME-BGC in different ecosystems is important to test the generality of its ecosystem process logic.

Other objectives were to test V0 of the ORNL DAAC to gain experience with EOSDIS, to further test BIOME-BGC code by working with other users, work with long-term data sets to test BIOME-BGC sensitivity to global climatic change,

Travel

Attended Oak Ridge National Laboratory Distributed Active Archive Center (ORNL DAAC) User Working Group meeting, 3-5 August 1994. We prioritized in rank as the most scientifically important various data sets to be incorporated into the ORNL DAAC. Particularly important for MODIS is the plan to perform a literature review of net primary production values

Participated in NASA's Terrestrial Ecology Program peer review panel to render advice on the importance and suitability for funding of unsolicited proposals, 19-20 September 1994.

Trip to Scripps Institution of Oceanography, 26 November to 2 December 1994 to finish global simulations and prepare manuscript.

Work Accomplished

Global Simulations using BIOME-BGC

BIOME-BGC (for BioGeochemical Cycles) was modified into a global model of Net Ecosystem Exchange (NEE) of CO2 incorporating the 7 land cover types defined by Running et al. (1994). Using a resolution of 1¯ latitude by 1¯ longitude grid cells of the land surface, we are attempting to validate the output of global version by comparing model outputs with the monthly atmospheric CO_2 concentrations measured at Mauna Loa and other stations around the world.

The highlight of the last 6 months was the completion of the final set of global simulations of net primary production (NPP) and heterotrophic respiration (Rh) in a collaborative project with Charles David Keeling and Steve C. Piper. The current version used a more consistent parameter set and corrected data layers. The result was 52 Pg carbon for global npp (Figure 1) and 53 Pg for global Rh (Figure 2). These results are unique as other global carbon models assume potential vegetation and use mean monthly climatic data, whereas we used actual daily climate data and NDVI for the year 1987. The difference is net ecosystem exchange (NEE) and simulated daily NEE was used as inputs to an atmospheric transport model. We then compared simulated and measured atmospheric CO_2 concentrations for validation (Figure 3). We were reasonably consistent with measured data for the northern hemisphere (Figure 3A) but not for the southern hemisphere (Figure 3B). The northern hemisphere is dominated by terrestrial ecosystems whereas the souther hemisphere is dominated by the oceans. Currently, these results are being prepared for publication.

Results from FIFE data analysis

The transition from essentially one-dimensional calculations to three-dimensional, landscape scale simulations requires the introduction of such factors as meteorology, climatology, and geomorphology. By using remotely sensed geographic information data for important model inputs, process-based ecosystem simulations at a variety of scales are possible. The second objective of this study is concerned with determining the accuracy of the estimated fluxes from BIOME-BGC, when extrapolated spatially over the entire 15-km by 15-km FIFE site. To accomplish this objective, a topographically distributed map of soil depth at the FIFE site was developed according to the method of Zheng et al. (in press). These spatially-distributed fluxes were then tested with data from aircraft by eddy-flux correlation obtained during the FIFE experiment.

Six site description variables were identified that could be acquired using standard remote sensing and GIS techniques. These variables are: elevation, slope, aspect, soil depth, land cover type, and leaf area index. To execute the model for each grid cell we will create 530 by 530 (30m resolution) binary files for the six variables and use them as input. An image of forest cover and an image of croplands were combined to create the cover type coverage (Figure 2). This image will determine which physiological pathway the model will follow. The oak forests were defined for model parameterization as deciduous broadleaf forest, the croplands as C3 grasslands, and the tallgrass prairie as C4 grasslands.

Data were available through the FIFE Information System on a series of five CD-ROMs (Strebel et al. 1992). A digital elevation model (DEM), and images of slope and aspect were available on volume 5 from Frank Davis. All maps were coregistered to a 30 meter by 30 meter ground spatial resolution, using the UTM projection. Slope and aspect were derived by taking local derivatives of elevation in the x and y direction. Soil depth was estimated using maximum and mean values of soil depth in conjunction with a topographic index, ln(‡/tan·) where ‡ is the area that drains through a given cell on the DEM and ¸ is the slope of the cell, using the method of Zheng et al. (in press).

Leaf area index (LAI) is the only variable that was altered through the year, so images of LAI were created for three FIFE "golden days" during the summer of 1987 (June 6, July 11, August 15). These days are optimum because satellite observations and surface-flux data are complete. LAI was determined using Landsat-TM imagery (Figure 4) for the three golden days. The most commonly used ratio is the normalized differential vegetation index (NDVI):

$$NDVI = (NIR - RED)/(NIR + RED) \qquad (1)$$

where NIR is reflectance from the ground surface in wavelengths between 0.76 and 0.90 Êm, and RED is the reflectance between 0.63 and 0.69 Êm for Landsat-TM images. LAI was determined from NDVI using the SAIL model (K. F. Huemmrich, personal communication), which assumes an exponential relationship between NDVI and LAI:

$$LAI = -\ln\left((NDVIx - NDVI) / NDVId\right) / k \qquad (2)$$

where NDVIx is the NDVI value for an infinitely thick canopy, measured to be 0.877 for a tall-grass prairie; and NDVId is the difference between NDVIx and the NDVI of the background, equal to 0.454, and k, the extinction coefficient, is 0.834 (K. F. Huemmrich, personal communication).

We display the simulated evapotranspiration (Figure 5) and net ecosystem exchange (Figure 6) for 530 by 530 pixels for the entire FIFE site for 2 dates. Figure 7 shows the differences between these two dates (August simulations - June simulations). We picked these dates because the vegetation shows the greatest differences in LAI. In June values of ET are highest in the deciduous forests and lowest in the croplands. Values are higher across the image on August 15 because: a large storm on August 13 that recharged the soil; very high net radiation; and very high vapor pressure deficit. The largest differences in NEE were found in areas of deciduous forest and occupying the steepest slopes and croplands which went from 0 LAI in June to maximum LAI in August. Surprisingly, NEE remains approximately constant between the two dates, although both photosynthesis and respiration decreased in August compared to June, due to a lower LAI.

Of the two dates, presented in this study, only August 15, 1987, has corresponding aircraft eddy-flux correlation data from Desjardins et al. (Journal of Geophysical Research, FIFE Special Issue, 1992) for comparison to the predictions. We are currently comparing flux measurements for July 11, 1987 and for the FIFE-89 Campaign. The predicted and measured fluxes have different units and different temporal scales; hence the null hypothesis is that the predictions and measured values are not correlated. We found a significant relationship between measured and predicted NEE, thereby rejecting the null hypothesis.

The R2 is not what we would consider high, only 0.27, indicating we have not explained most of the variance of NEE at the FIFE site for this date. However, previous validations comparing NPP along the Oregon transect occurred over a very large change in precipitation, hence a higher R2 was expected there. We are continuing to analyze these data.

Other work accomplished.

The work from New Brunswick and Oak Ridge are going well, much of the data are still being analyzed. I am planning to present seminars on both sets of work in late February, 1995. Several graduate students are testing BIOME-BGC extensively themselves, and I spent considerable time checking up on their questions about the code and results.

Publications:

Kremer, R. G., E. R. Hunt, Jr., S. W. Running, and J. C. Coughlan. 1994. Simulating vegetational and hydrologic responses to natural climatic variation and GCM-predicted climatic change in a semi-arid ecosystem in Washington, U.S.A. Journal of Arid Environments (in press).

Franklin, S. E., M. B. Lavigne, E. R. Hunt, B. A. Wilson, D. R. Peddle, G. J. McDermid, and P. T. Giles. In review. Topographic dependence of synthetic aperture radar imagery. IEEE Transactions on Geoscience and Remote Sensing.

Zheng, D., S.W. Running & E.R. Hunt, Jr. In review. Prediction of available soil water capacity based on topographic analysis for regional applications. Landscape Ecology.

Waring, R.H., J.B. Way, E.R. Hunt, Jr., L. Morrisey, R. Oren, J. Ranson, & J.Weishampel. In review. Remote sensing with radar in ecosystem studies. Bioscience.

Hunt, E. R., Jr. (in preparation). Effects of climatic data resolution on ecosystem processes: Testing the simulation Model, BIOME-BGC, with flux data from the FIFE experiment. Agricultural and Forest Meteorology.

Rollins, M. G. (in preparation). Comparing simulated and measured H_2O and CO_2 fluxes spatially over the 15-km by 15-km FIFE site. MS Thesis, University of Montana, Missoula.

Rollins, M. G. and E. R. Hunt, Jr. (in preparation). Comparing H2O and CO2 fluxes measured with eddy-flux aircraft with predictions from an ecosystem process model for the 15-km by 15-km FIFE site.

Hunt, E. R., Jr., R. Nemani, S. C. Piper, S. W. Running, C. D. Keeling. (in preparation). Global net carbon exchange and intra-annual atmospheric CO2 concentrations predicted by an ecosystem simulation model and three-dimensional atmospheric transport model.

Hidayat, A. & E.R. Hunt, Jr. Submitted. Relationship of AVHRR-NDVI to seasonal drought for an evergreen tropical rainforest in Ujung Kulon, Indonesia. International Journal of Remote Sensing.

Presentations

Hunt, E. R., Jr. Invited Seminar to the Botany and Geography Departments, University of Wyoming entitled, "Estimation of Ecosystem Carbon Fluxes at Local and Global Scales," 16 September 1994.

Rollins, M. G. 1994. Comparing measured and simulated evapotranspiration for the FIFE site. Annual Meeting of the Montana Chapter, American Water Resources Association.

ACTIVITIES OF R. Nemani, Assoc Team Member

OBJECTIVES

My objectives were to 1) revise ATBD for LAI and FPAR products, 2) continue development and testing of land cover classification logic, 3) estimation of global land cover change and its impacts on climate and carbon cycles.

Work Accomplished

Algorithm Technical Basis Document (ATBD)

Over the last six months, ATBD for MODIS products # 14 (Leaf Area Index) and # 15 (FPAR) was revised to include reviewer's comments. The 3-D radiative transfer model of Myneni was customized to produce a look-up-table (LUT) of LAI and FPAR for global grasslands, to be used in conjunction with AVHRR/Pathfinder data. Ancilliary information on soils, leaf optical properties and phenology is being assembled for grasslands. We will produce a first generation LAI/FPAR product for global grasslands using the LUT approach customized for AVHRR/Pathfinder (8 km) data.

Land cover classification

A simple remote sensing based land cover classification scheme was developed for regional to global applications. This logic was tested over the continental U.S with reasonable success. Global implementation of this logic is being pursued with the recently available AVHRR/Pathfinder data.

Meetings Attended

MODIS Science Team Meeting, October 1994
IGBP Workshop "Plant Functional Types", November 1994, Potsdam, Germany
AGU Fall meeting, December 1994

Publications

Nemani, R., and S. Running. 1995. Land cover classification using multi-temporal red, nir and thermal IR AVHRR data. Ecological Applications (in review)

Nemani, R., and S. Running. 1995. Global vegetation cover changes from satellite data. Journal of Geophysical Research-Atmosphere (in review)

Nemani, R., and S. Running. 1995. Satellite monitoring of global land cover changes and their impact on climate. Climatic change (in review)

Nemani, R., and S. Running. 1995. Satellite mapping of global biome distribution and simulated variability in biospheric processes. Journal of Vegetation Science (in review).

Presentations

'Global land cover changes and their impact on climate', AGU Fall meeting, December 1994.

"The proposed MODIS Vegetation Classification logic" IGBP Meeting on Plant Functional Types, Potsdam, Germany

On-going Activities

LAI and FPAR Products

Analyze the 3-D model output to find simple ways to correct for background and viewing geometry.

Land cover classification

The generality of our logic is being tested with AVHRR data collected over various climate and vegetation conditions around the globe. This work is being pursued in collaboration with Dr. Strahler (U. of Boston), Dr. Eric Lambin (JRC, Ispra) and Tom Loveland (EROS Data Center).

Global land cover change

We are starting to work with various climate modeling groups to analyze the impacts of changes in land cover on global temperatures.

ACTIVITIES OF J.M.GLASSY, Software Engineer

OBJECTIVES

My objectives were to 1) revise the Programming and Practical Constraints section of the FPAR~LAI ATBD, 2) continue working on the design and implementation of the FPAR~LAI MODIS algorithm codes, 3) investigate alterative sources for global scale daily climatology datasets suitable for use in our NPP algorithm, 4) locate and retrieve key input datasets for algorithm development, and 5) continue development of the Univ. Montana SCF software/hardware infrastructure.

WORK ACCOMPLISHED

FPAR~LAI ATBD Programming section revisions

Several iterations on the design concept and implementation of our FPAR~LAI Algorithm product have been performed during this period. A revised Programming and Practical Constraints section for our FPAR~LAI ATBD has been completed, added needed detail to the process and data flow diagrams, as well as documenting our latest FPAR~LAI lookup table (LUT) design.

FPAR~LAI Algorithm Code Development

Progress in the FPAR algorithm development effort has been made during this period on both the design and prototype implementation fronts. A draft Algorithm Implementation Plan (AIP) for the FPAR~LAI product set has been completed; this plan describes the specific methodology and procedural detail required to implement the algorithm in software. For the prototype effort, a hierarchical software architecture has been adopted, underpinned by the EOSDIS Science Data Production (SDP) Toolkit v.3 and the forthcoming SDST Toolkit. A base software service layer (MODIS~Univ. Montana, or MUM) has been designed to provide function services shared by all MODIS algorithms our local SCF is responsible for. A prototype MUM API has been implemented, currently as a simple application programming interface (API) designed to be compatible with the SDP Tk v.3 and the SDST Toolkit. The particular algorithm codes (FPAR~LAI, NPP, and eventually ET and surface resistance) are all built on top of the MUM software layer services.

The FPAR~LAI algorithm is now designed to include two major segments: a LUT generation phase, and a LUT client phase. The LUT itself is being generated using the 3-D Myneni radiative transfer (R-T codes) model modified for our production use at the SCF. A working prototype of the Myneni model is now available, and is now undergoing testing. The LUT client software will be the user's interface to the final LUT, and thus represents the main deliverable. In a parallel effort to the LUT generation activities, synthetic LUTs have now been generated using custom SCF software, for use in testing the prototype LUT client software.

Incremental improvements in the LUT client logic have been made, and once a verified generation of the prototype global scale GRASS biome lookup table is available later this spring, full up tests may begin on the LUT client software. A trial build of the

EOSDIS SDP Toolkit v.3 has now been made; problems in the build sources have prevented us thus far from testing the toolkit, however; we are in the process of getting these resolved. Support software packages retrieved and built include the Global Cartographic Transform Package (GCTPc), the MapGen and GMT mapping support toolsets, as well as the utilities offered by the AVHRR Pathfinder team (goodes, hdftobin.sh etc). We now have available a full set of software for processing the special science data formats (HDF, CDF, netCDF) that the AVHRR Pathfinder data is supplied in.

Identification of Global Scale Algorithm Input Datasets

For the NPP algorithm development effort, a global scale daily climatology ancillary dataset has been identified that should suit our needs. SDST staff Rich Hueck and NOAA's Robert Kistler were instrumental in helping connect us to the NOAA/NMC gridded climate dataset (e.g. gdas1.T00Z.SFLUXGrbF06, etc). NOAA supplied software for processing these NMC datasets (BUFR and GRIB sources) has been retrieved and is being evaluated.

For the FPAR~LAI algorithm, a proxy dataset for the MODIS instrument providing global coverage has been identified -- the NASA AHVRR Pathfinder data products. Significant portions of these data have already been retrieved onto the SCF facility (1989, and portions of 1990). This global scale (8K resolution) contains 5004x2168 pixels per layer, with each granule requiring approximately 227MB when uncompressed. Currently we have ordered and received data for the full 1989 period (36 granules), with additional orders placed for 1988, 1987, and 1990 AVHRR data. Software facilities for processing this HDF/netCDF format data are in place and have been tested.

Development of the Univ. Montana SCF Infrastructure

Significant progress has been made during this period in the development of the Univ. Montana SCF facility. Several new IBM RS/6000 41T class (PowerPC) workstations have now been delivered and integrated into the SCF cluster, along with a growing complement of high capacity disk drives. Data handling software built on the SCF now includes full implementations of software for processing the HDF, CDF, netCDF science data formats. Data analysis and program development software now installed include Splus/Trellis v.3.2 statistical software, Mathematica v.2.2.1 for MS-Windows, IBM's FORTRAN 77 and C compilers, and a suite of public domain packages have now been built on the SCF cluster: (PVM, IPW v.1.0, GCTPc, Mapgen, GMT, PBMPlus, Tcl/Tk/Wish, GNU gcc and utilities, etc). Packages now on order include the IBM Fortran-90 and C/C++ Software Workbench products and the Recital RDBMS package. The Khoros and IDL software packages are also under consideration. Our collaborator Dr. Myneni has a collection of IDL routines we intend to use for validation and interpretation of the 3-D R-T model outputs.

MEETINGS ATTENDED

I attended the NASA MODIS Science Team Meeting held at College Park, MD in October of this year. Significant contacts were established between our SCF and the TLCF and SDST leadership, as well as the MODLAND team leadership.

ON-GOING ACTIVITIES

The on-going activities now underway include continued refinement of the FPAR~LAI LUT client codes and the design of a 3-D R-T model execution environment that will allow us to take advantage of asyncronous parallel processing using a collection of our RS/6000 workstations. Special attention is being paid to the execution of the 3-D R-T model used to generate the FPAR~LAI LUT due to its computational complexity. The PVM suite from ORNL is currently under evaluation at our SCF.

Design and a prototype implementation has also progressed on a MUM based RPC task-dispatching/merge software application: tasktiler, a part of the MUM software layer. This master/slave application is designed as a cooperative set of shell scripts and C codes that dispatch a set of independent tasks (from a queue) to a set of slave workstations. The master periodically polls the asyncronous slaves, and when all of these return a "status complete" message, the master application merges all slave outputs into a single final output product.
from july 1994

FIGURE LEGENDS

Figure 1. Global net primary production during 1987 for 1¯ latitude by 1¯ longitude grid cells. Actual gridded daily climatic data for 1987 and leaf area index from 1987 NDVI were used as inputs to BIOME-BGC.

Figure 2. Global heterotrophic respiration during 1987 for 1¯ latitude by 1¯ longitude grid cells.

Figure 3. Comparison of simulated and measured atmospheric CO2 concentrations for 1987 at (A) Mauna Loa and (B) South Pole. The solid line is predicted atmospheric CO2 concentration from
BIOME-BGC simulations, the dashed line is from Keeling's previous model results published in an American Geophysical Union monograph (AGU composite), and the dotted line are the measured data. The CO2 concentrations were scaled to the mean annual CO2 concentration to emphasize deviations from the mean.

Figure 4. Leaf Area Index for the FIFE Site: (A) June 12, 1987 and (B) August 15, 1987. LAI was determined using the SAIL model,
which was parameterized for the FIFE site by Fred Hummerich. Radiometrically corrected Thematic Mapper data from the FIFE CD-ROM set was used to determine LAI for various dates during 1987, only two dates are shown here. The LAI ranges are:

Black:	0
Blue:	0.1 to 1.0

Green: 1.1 to 2.0
Yellow: 2.1 to 3.0
Red: 3.1 to 5.0

The higher values of LAI (red) correspond to areas of gallery oak forest, and for crops in August. A shift in LAI for areas of tallgrass prairie may be seen, with generally lower values in August compared to June.

Figure 5. Simulated evapotranspiration for the FIFE site: (A) June 12, 1987 and (B) August 15, 1987. Daily evapotranspiration (ET, mm/day) is the sum of transpiration from the vegetation and evaporation from the soil for these two dates. The ET ranges are:

Black:	0
Blue:	0.1 to 3.0 mm/day
Green:	3.1 to 4.0 mm/day
Yellow-green:	4.1 to 5.0 mm/day
Yellow:	5.1 to 6.0 mm/day
Orange:	6.1 to 7.0 mm/day
Red:	7.1 to 8.0 mm/day

Figure 6. Simulated net ecosystem exchange for the FIFE site: (A) June 12, 1987 and (B) August 15, 1987. Daily net ecosystem exchange (NEE, g C/m2/day) is daily photosynthesis net autotrophic and heterotrophic respiration. The NEE ranges are:

Black:	< -50 g C/m2/day
Gray:	-50 to 0 g C/m2/day
Blue:	0.1 to 10 g C/m2/day
Green:	11 to 30 g C/m2/day
Yellow-green:	31 to 50 g C/m2/day
Yellow:	51 to 70 g C/m2/day
Red	> 71 g C/m2/day

Negative NEE indicates that autotrophic and heterotrophic respiration are greater than daily photosynthesis.

Figure 7. Differences between August 13 and June 12 of: (A) Evapotranspiration and (B) Net Ecosystem Exchange. The ranges of difference in ET (August 13 value - June 12 value) are:

Black:	0 to 1.0 mm/day
Blue:	1.1 to 2.0 mm/day
Green:	2.1 to 3.0 mm/day
Yellow:	3.1 to 4.0 mm/day
Orange:	4.1 to 5.0 mm/day
Red:	5.1 to 7.5 mm/day

and the ranges of difference in NEE (August 13 value - June 12 value) are:

Gray:	0 g C/m2/day
Blue:	0.1 to 10 g C/m2/day
Green:	11 to 30 g C/m2/day
Yellow:	31 to 50 g C/m2/day
Orange:	51 to 70 g C/m2/day
Red:	71 to 92 g C/m2/day

Figure 8. Correlation between predicted net ecosystem exchange and aircraft eddy-flux correlation data. BIOME-BGC predictions of daily net ecosystem exchange (NEE) g C m-2 day-1 and NEE measured using aircraft eddy-flux correlation by Desjardins et al. (1992). The foot print of the eddy flux aircraft was 66 by 32 pixels, resulting in 32 grid cells for the FIFE site, so the simulated fluxes were averaged within the foot print.